Reply to comment by W. F. Ruddiman on "A note on the relationship between ice core methane concentrations and insolation"

Gavin A. Schmidt and Drew T. Shindell

NASA Goddard Institute for Space Studies and Center for Climate Systems Research, Columbia University, New York, New York, USA

Susan Harder

Environmental Science Program, Washington State University, Vancouver, Washington, USA

Received 14 March 2005; revised 21 June 2005; accepted 28 June 2005; published 4 August 2005.

Citation: Schmidt, G. A., D. T. Shindell, and S. Harder (2005), Reply to comment by W. F. Ruddiman on ''A note on the relationship between ice core methane concentrations and insolation,'' *Geophys. Res. Lett.*, *32*, L15704, doi:10.1029/2005GL022982.

[1] *Schmidt et al.* [2004] pointed out that linear correlations between CH_4 and insolation used by *Ruddiman* [2003] to project CH_4 trends over the Holocene were not appropriate. We note that this principal point of our paper is not disputed by *Ruddiman* [2005b]. Instead, Ruddiman's comment uses an analogy with the end of Stage 11 to support his hypothesis: an argument that is not made by *Ruddiman* [2003], although it is made by *Ruddiman* [2005a] and was briefly addressed by *Schmidt et al.* [2004]. This analogy depends on one principle issue: the association of uncertain timing of the end of Stage 11 in Vostok, EPICA Dome C and ocean sediment cores [*McManus et al.*, 2003] to the (well-dated) changes in insolation (the implicit link between Figures 1a and 1b by *Ruddiman* [2005b]). We maintain that dating uncertainties preclude such a strong identification, while Ruddiman does not. We do not dispute the size of CH_4 changes at glacial inception, only whether glacial inception was to be expected in the Holocene. Much of the response to Ruddiman's comment is already clearly covered by *Schmidt et al.* [2004], but we nevertheless address his four points in turn.

[2] Ruddiman appears to overinterpret the quality of the dating for Vostok and EPICA Dome C. *Petit et al.* [1999] use an orbital control point at 390 kyr and estimate an error of 15 kyr. *Delmotte et al.* [2004] also suggests an error of at least 10 kyr in Vostok. Similarly the EPICA dating does not claim an absolute accuracy of better than 10 to 12 kyr (J. Jouzel, personal communication). The *Bender* [2002] timescale also has a control point at 385 kyr which, even if correct, still leaves some uncertainty over the older part. The key point is that given the uncertainties of dating, all that can be said with certainty is that Stage 11 extended over more than one and half precessional cycles [*McManus et al.*, 2003]. That is, for at least one insolation decrease at a period of low eccentricity there was no concomitant change in CH_4 or ice volume. This counter-example stands in clear contrast to Ruddiman's hypothesis.

0094-8276/05/2005GL022982$05.00

[3] Ruddiman's point is based on a misreading of the analysis of *Chappellaz et al.* [1997]. They do not find the interpolar CH_4 gradient decreasing during the last 4,000 years. For the entire period 5–2.5 kyr BP, *Chappellaz et al.* [1997, Figure 4] calculate the average gradient and state that during the Holocene the largest difference between Greenland and Antarctica is observed during this time. They go on to say (p. 15,994), "Our model suggests, as an explanation, a concomitant decrease of the tropical source and an increase of the boreal source." Only after 2.5 kyr BP can it be argued that the gradient decreases, though they do not calculate and model another gradient until the period spanning 1–0.25 kyr BP. This difference is smaller and does suggest an increase in tropical emissions as the source for the CH_4 increase at this later time.

[4] River deltas have increased in scope globally in the late Holocene and there is no obvious anomaly associated with any hypothesised (and as yet completely unquantified) anthropogenic contributions to river deltas in Eurasia compared with those elsewhere.

[5] We are a little puzzled that Ruddiman appears not to have noticed the multiple statements in our paper where we state explicitly that we do not think that CH_4 can be purely linked to precessional insolation. However, it was because *Ruddiman* [2003, Figure 1] implicitly does that prompted our note in the first place.

[6] In summary, we continue to maintain that in the absence of further studies ruling out boreal wetlands, tropical river deltas and peat lands as sources of the late Holocene increase in CH_4 emissions, a definitive attribution [*Ruddiman*, 2005b] of this trend to anthropogenic sources is premature.

References

Bender, M. (2002), Orbital tuning chronology for the Vostok climate record supported by trapped gas comparison, *Earth Planet. Sci. Lett.*, *204*, 275–289.

Chappellaz, J., T. Blunier, S. Kints, A. Dällenbach, J.-M. Barnola, J. Schwander, D. Raynaud, and B. Stauffer (1997), Changes in the atmospheric CH_4 gradient between Greenland and Antarctica during the Holocene, *J. Geophys. Res.*, *102*, 15,987–15,999.

Delmotte, M., J. Chappellaz, E. Brook, P. Yiou, J. M. Barnola, C. Goujon, D. Raynaud, and V. I. Lipenkov (2004), Atmospheric methane during the last four glacial-interglacial cycles: Rapid changes and their link with Antarctic temperature, *J. Geophys. Res.*, *109*, D12104, doi:10.1029/2003JD004417.

McManus, J., D. Oppo, J. Cullen, and S. Healey (2003), Marine Isotope Stage 11 (MIS 11): An analog for Holocene and future climate?, in *Earth's Climate and Orbital Eccentricity: The Marine Isotope Stage 11*

Question, *Geophys. Monogr. Ser.*, vol. 137, edited by A. W. Droxler, R. Z. Poore, and L. H. Burckle, pp. 69–85, AGU, Washington, D. C.

Petit, J. R., et al. (1999), Climate and atmospheric history of the past 420,000 years from the Vostok ice core, *Nature*, *399*, 429–436.

Ruddiman, W. F. (2003), The anthropogenic greenhouse era began thousands of years ago, *Clim. Change*, *61*, 261–293.

Ruddiman, W. F. (2005a), Cold climate during closest Stage 11 analog to recent millennia, *Quat. Sci. Rev.*, *24*, 1111–1121.

Ruddiman, W. F. (2005b), Comment on "A note on the relationship between ice core methane concentrations and insolation" by G. A. Schmidt et al., *Geophys. Res. Lett.*, *32*, L15703, doi:10.1029/2005GL022599.

Schmidt, G. A., D. T. Shindell, and S. Harder (2004), A note on the relationship between ice core methane concentrations and insolation, *Geophys. Res. Lett.*, *31*, L23206, doi:10.1029/2004GL021083.

S. Harder, Environmental Science Program, Washington State University, 14204 NE Salmon Creek Avenue, Vancouver, WA 98686, USA. (harders@vancouver.wsu.edu)

G. A. Schmidt and D. T. Shindell, NASA Goddard Institute for Space Studies and Center for Climate Systems Research, Columbia University, 2880 Broadway, New York, NY 10025, USA. (gschmidt@giss.nasa.gov)